Deloitte & Touche

A PRELIMINARY IDENTIFICATION OF STRATEGIC OPPORTUNITIES FOR DEVELOPMENT OF BIO-CONTROL AND INOVULANT PRODUCTS IN CANADA

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May 15, 1990

Dear Terry:

We are pleased to present our findings from our Preliminary Identification of Strategic Opportunities for Development of Bio-Control and Inoculant Products in Canada. Our findings suggest that the area holds promise for successful commercial development in Canada. Nevertheless, given the current range and depth of unknowns plus the time requirements and risks associated with the development, we believe that it is very important that Canada focus its effort on a very limited number of strategic opportunity areas. Development of such a focus will need a more detailed quantitative and qualitative look at the potential for these areas.

We would be pleased to assist in this task should there be an opportunity to do so. Thank you for the opportunity to work on this interesting area.

Yours sincerely,
DELOITTE & TOUCHE

Richard A. Broadwith
Director
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/tb

Enclosure

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For:

Industry Science & Technology

Prepared by:

Deloitte & Touche

Deloitte & Touche

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EXECUTIVE SUMMARY

Deloitte & Touche conducted a preliminary study to identify strategic opportunity areas for Canada in the field of microbial pesticides and inoculants. The study was commissioned by Industry Science & Technology Canada (ISTC).

Our approach involved interviews and discussions with a sample of key people drawn from universities, government research and regulatory agencies and the business community active in the microbial research and product development areas.

Reference was made to published scientific papers and articles, in house information and industry data to determine the significance of pest, weed and disease problems and opportunities for inoculants.

Our findings from this preliminary study are:

1. Naturally occurring microbial control agents and inoculants offer promise as effective products for use in agriculture and forestry.

2. There is a significant amount of research currently underway on microbial control agents in Canada but much of it is focused on solutions to specific problems and consequently is a reaction to existing conditions, not a strategic initiative. There are exceptions to these observations but the level of success in these cases is low.

3. Research on inoculants in Canada is also extensive and has been quite successful when product development is based on well known micro organisms. Much less success has been achieved where product development has been based on novel concepts.

4. Conclusions 2 and 3 above indicate a need for more basic research to gain further insights into the mode of action of new candidate control agents and inoculants and their applications and use in practical farming conditions.

5. Those people who are active in developing microbial products tend to underestimate the time required to bring such products to a commercial stage. Products based on improved strains of well known organisms can be expected to require a development period of a minimum of three years with five years being a more realistic estimate. Products based on new concepts will require much longer development periods. As more knowledge is accumulated, these development periods may be shortened but not by much.

6. Development costs have also been frequently underestimated. The direct costs for developing a new successful microbial control agent will rarely be less than one million dollars and for an inoculant it can be expected to be about $700,000. These figures do not include the cost of developing a production process or formulations and assume that no special problems are encountered during development.

7. Due to the novelty of this science there is a high risk that product development will encounter significant problems. It should be noted that one prominent firm, staffed by exceptional scientists, has spent $10.2 million over eight years and has yet to launch its first product.

8. The product development process must include study of the candidate micro-organism to ensure that its production and release are safe to man and the environment. The present cost of such studies in Canada is about three times higher than that in the U.S.A.

9. From these observations it is concluded that only major target opportunities are likely to be economically viable. These are as follows:

Herbicides	Insecticides	Fungicides	Inoculants
Wild Oats	Spruce budworm	Apple scab	Nitrogen fixation
Green Foxtail	Soil insects	Late blight	Phosphate solubilizing
Quack-grass	Corn rootworm	Botrytis	Growth stimulants
Noxious perennial weeds	Pests on vegetables	Soil diseases	
Perennial weeds in forests			

10. It is concluded that product development of naturally occurring micro-organisms will result in a significant expansion of scientific knowledge which will be useful in development of products based on genetically engineered micro-organisms (GEMS). Ultimately GEMS are likely to replace naturally occurring micro-organisms but this will take many years.

11. Since research activity on microbials in Canada by multinational corporations is limited for the most part to local testing of products developed elsewhere, other development mechanisms need to be examined. These might include stimulating research scientists by grants made for specific research which are conditional on acceptance of principles governing exploitation of successful research results.

12. The range of strategic opportunity areas identified may appear limited to some, and leave out many problem or opportunity areas for others. Regardless, this list is still far too extensive in terms of Canada's ability to mount any effective strategic initiatives. Significant progress will only be possible in a few of these areas given the scope of additional research and development requirements and the contingent resource requirements for commercialization.

RECOMMENDATIONS

Our preliminary research activities have identified a range of strategic opportunity areas for bio-control and inoculant products. These opportunities are based on preliminary assessments of the scale of opportunity, the nature of the problem area, and current control or treatment practices.

Our overwhelming response to the research is to recommend that there be a very significant focus of effort on very few (4-5) strategic opportunity areas. The effort should include activity on at least one herbicide, on fungicide, on insecticide and one or two inoculants. Only this level of focus can generate the depth of expertise, level of effort, recognition and potential for success in areas of significance. We believe that this is required to attract attention and support of multinational and serious domestic commercial investors. Moreover, it will provide a better environment for direct and serendipitous development of effective solutions to key target opportunities.

Consequently, it is important that the limited number of areas for study are selected with great care. In this respect it is mandatory that the nature and scale of opportunity areas be qualified and quantified in detail and that the scientific chances for success are reasonably favourable. We see attention to all of these points as essential prior to final designation of any strategic opportunity area.

The preliminary research activities have also identified a range of significant constraints to successful commercialization of bio-control and inoculant products, viz:

- the length of time, cost, risk and uncertainty associated with product development;
- limited understanding of the modes of action of bio-control and inoculant products;
- limited infrastructure and resources for commercialization of such products domestically and internationally;
- more conservative environmental and safety requirements than the United States;
- strong latent public concern about the environmental and human safety which could easily and realistically be transferred to this activity as more detailed information on the modes of action and control become known and public;
- a somewhat uncoordinated research and commercial development community.

Consequently, it is mandatory that the nature and scale of these issues and constraints be addressed in more detail if strategies are to be developed that ameliorate or obviate them so that strategic opportunities can be successfully addressed.

Notwithstanding there is a strong groundswell of enthusiasm and activity underway in this area. Continued support, leadership, direction and coordination will be required to foster this development along strategic lines.

1.0 INTRODUCTION

The Department of Industry, Science and Technology Canada (ISTC) seeks to identify strategic opportunities for Canada in the development of naturally occurring microbe-based products as control agents to combat pests, weeds and diseases and as inoculants to stimulate crop growth. This interest is based on a preliminary survey of the agricultural and food sectors conducted by a working group, established by the National Biotechnology Advisory Committee. The hypothesis developed from this activity was that the use of micro-organisms for these purposes could be developed without using expensive genetic engineering techniques and that the resulting products could lead to reduced pressures on the environment from chemical control agents and fertilizers.

Deloitte & Touche was commissioned by ISTC to provide preliminary identification and qualification of strategic commercial opportunity areas for microbial growth inoculation and bio-control of crop pests and diseases.

The objectives of this preliminary assessment were to:

- identify and categorize specific opportunity areas in growth stimulation
  - bio-herbicides
  - bio-insecticides
  - bio-fungicides

- assess current and prospective availability and use of microbial agents for these activities;

- assess the commercial relevance of prospective microbial growth stimulation and bio-control agents; and

- define more discrete areas of further research and evaluation of the strategic opportunities.

This preliminary report is based on:

(I) interviews with a sample of scientists, regulators and business people;

(II) review of published research papers and articles and statistics, and proceedings from a regulatory conference on naturally occurring microbial control agents;

(III) attendance at a conference on genetically altered microbials; and

(IV) published statistics on fertilizer and pesticide use from in-house market information and confidential market information supplied by Ciba-Geigy Limited on pesticide use.

Fourteen interviews each lasting one to four hours were face to face. Ten interviews were conducted over the telephone. Ten interviews were conducted in Ottawa at a conference on regulation of genetically altered microbials. A number of supplementary telephone interviews were conducted with respondents to clarify and expand on issues.

The majority of those interviewed were located in Canada but there were four in the U.S.A. and two in Switzerland (See Appendix I).

The sample of 34 respondents was drawn from the following sectors:

Federal Government Research	6
Provincial Government	2
Universities	4
Companies in microbials	10
Chemical companies	5
Regulatory officials	4
Other	3
TOTAL	34

We would add that the views expressed in this report reflect some but not all of the views expressed by participants in our sector survey activities.

2.0 RESEARCH ISSUES

Microflora and microfauna that can be used to control pests, weeds or diseases are regulated under the Pest Control Products Act which is administered by the Pesticides Directorate of Agriculture Canada. The Directorate defines products containing these micro-organisms as naturally occurring microbial control agents. There are four potential ways in which these agents may work. (See Figure 1)

Microflora and microfauna that can be used to stimulate crop growth are regulated under the Fertilizer Act which is administered by the Feed & Fertilizer Directorate of Agriculture Canada. Such products are typically applied directly to the soil or by treating seed and are defined as inoculants. So far these inoculants have been shown to work in four ways. (See Figure 2)

2.1 Research on Microbial Control Agents in Canada

There is a range of research and product development activities underway in Canada in this area.

Research activity has concentrated mainly on insect control but weed and disease control have also received attention. Insect control studies have centred mainly on improving the activity of Bacillus thuringiensis (Bt) by enhancing its toxicity and broadening its spectrum to include other insect families besides the Lepidoptera. This work has been underway to varying degrees since Bt was first registered for sale in Canada in 1962. This research received a boost in the early 1980's with the realization that biotechnology might enhance Bt performance but much of this work is done outside of Canada. One multinational corporation has its Bt research based in Canada and concentrates its effort on the selection of naturally occurring strains of high potency.

Figure 1 **Potential Modes of Action of Microbial Control Agents**

1.	Microbe synthesizes toxins in a man made factory	Many Microbes Die	Toxin applied to target	Target Controlled
2.	Microbe multiplied in a man made factory	Microbe applied to target	Microbe produces toxin on site	Target Controlled
3.	Microbe multiplied in a man made factory	Microbe applied to target	Microbe infects target	Target Controlled
4.	Microbe multiplied in a man made factory	Microbe applied to crop	Microbe affects target pathogen	Target pathogen prevented from damaging crop

Figure 2 **Potential Modes of Action of Inoculant Microbial Agents**

1.	Microbe multiplied in a man made factory	Microbe applied to soil/seed, invades crop roots and produces nodules	Microbes in nodules convert nitrogen from the air into plant food for the crop	Crop utilizes plant food
2.	Microbe multiplied in a man made factory	Microbe applied to soil/seed and microbes convert insoluble phosphates in the soil to soluble form	Crop takes up solubilized phosphates	Crop uses phosphorous as plant food
3.	Fungus produced by man on growing plants	Fungus applied to soil. Fungus takes up phosphorous from the soil and transports it to fungus within roots	Phosphorous exchanged in the root	Crop uses phosphorous as plant food
4.	Microbe multiplied in a man made factory	Microbe applied to crop	Microbe stimulates germination and root growth	Crop emergence and early growth improved. Yields may be increased.

Research on control of agricultural insect pests with other microbial organisms includes the use of protozoa against grasshoppers. Nosema locustrae is the organism used. It is effective against all grasshopper species tested, but the control process is so slow that it is not commercially acceptable for controlling infestations on crops. It might have an application on rangeland and other areas where rapid control is not mandatory. One scientist reported that Nosema spp. had been detected in the bloodstream of AIDS patients and pointed out that this might slow down the development of this type of biocontrol agent pending a better understanding of the relationship, if any, between the protozoa and AIDS.

A number of organizations are studying the use of viruses to control agricultural and forest insect pests. The Forest Pest Management Institute (Forestry Canada) has been successful in this area and has the only PCP registrations for viral control agents in Canada.

Weed control with microbial control agents has been the subject of study at a few locations and has met with some success. One product containing Colletotrichum glecosponeides f. sp. malvae and claimed to control round leaved mallow selectively in crops has shown good but sometimes slow performance in the field and may be introduced commercially if regulatory requirements can be met. Patents have been issued on the use of this organism in Europe. A second organism for the control of field bindweed has shown promise but the decision to market it has not yet been taken. In both cases, control of the target weed by chemical means is not at present satisfactory. There are a number of other potential bioherbicides at earlier stages of development but some have shown unreliable results in the field. A few of these have a moderately broad spectrum of control.

Less success has been achieved so far in the search for microbial agents for disease control. The largest agricultural biotechnology company in Canada achieved success in controlling diseases in the laboratory and greenhouse but so far has failed to duplicate these results in the field. Opinion is divided as to the difficulty in solving this problem. One respondent believes it will take 8-12 years before the problem can be overcome. A second believes the problem is due to the micro-organism dying before it is applied in the field and that the solution lies in improved formulation, and to finding a medium in which the micro-organism can be kept alive from the time it is produced in the factory until it reaches the field. Research is underway on this subject. There are a number of theories on the mode of action of this agent but none have been scientifically proved to date.

Effective microbial control agents for the control of Botrytis on strawberries have been isolated at O.A.C., Guelph. Reliable control in the field with these agents has been demonstrated but the control mechanism has not been investigated. Control of diseases on other crops is underway at a number of centres.

2.2 Research on Inoculants in Canada

The use of bacterial inoculants for nitrogen fixation on leguminous crops has been a commercial agricultural practice for many years. Methods for enhancing nitrogen fixation in other crops have been the subject of much research but no success has been achieved.

Research on other types of inoculant to stimulate growth is taking place at several locations in Canada. Work is most advanced on the use of Penicillium bilaji as a phosphorous solubilizing agent and a product containing this agent will be introduced for use on wheat in Canada in 1990. Patents for the use of this organism have been filed in many countries. So far the Republic of South Africa is the only country in which the patent has been issued.

Less advanced is work to determine if there is a place for inoculants based on mycorrhiza. Performance has been confirmed on corn when phosphate levels are low but so far there has been no demonstrated growth stimulation when available phosphate in the soil is adequate. It is believed there may be symbiosis between Penicillium bilaji and mycorrhiza. Current production costs are high so products based on these fungi can only be used economically on high value crops and on the home and garden market. One such product is available in the U.S.A. and a second is being developed in Canada.

One company has adopted a more radical approach in the inoculant field and has determined that germination and root growth in the young plant can be speeded up by the application of plant growth promoting rhizobacteria (PGPR's). Applied to the plant they change its histology and can induce increased root growth by 80-100%. Registration of a product of this type for use on Canola is in progress under the Fertilizer Act. Its mode of action ,when understood more fully, could conceivably make it subject to regulation under the PCP Act as a growth regulator.

3.0 DEVELOPMENT ISSUES

In order to appreciate the full complexity of bringing a microbial product to the point of commercial introduction development can be divided into a number of stages. These development stages for microbial control agents are illustrated in Figure 3 and described in Section 3.1. A discussion of the time required and costs incurred for development is in Section 3.2. Inoculant development, similarly is illustrated in Figure 4. The cost and development time required, are identified in Sections 3.3 and 3.4. Development of production methods and formulations are described in Sections 3.5 - 3.7.

3.1 Stages in the Development of Naturally Occurring Microbial Control Agents

Stage 1 Collection and Maintenance of Species and Strains

The first step in identifying effective naturally occurring microbial agents is to collect and isolate candidate organisms from the appropriate habitat and maintain these collections in the laboratory. When the research project is in its early stages, the collections may include numerous species. Botrytis control on strawberries typifies this type of collection. A number of species of fungi and bacteria were collected from strawberry plants, identified and cultured.

If research is more advanced collections may be confined to a single species in an attempt to identify more virulent strains within the species. Bt is an example of this type of collection. This stage can often be completed in a single growing season.

Stage 2 Laboratory Screening

After the species/strains have been isolated, their activity is screened in the laboratory against the target organism. This process is similar to the early screening of chemical pesticides. The most active agents are selected for further testing. Once effective screening techniques have been developed, this stage can proceed quite rapidly. In some situations this step is omitted and primary screening takes place in the greenhouse.

FIGURE 3 BIO-CONTROL - PATHWAYS OF DEVELOPMENT

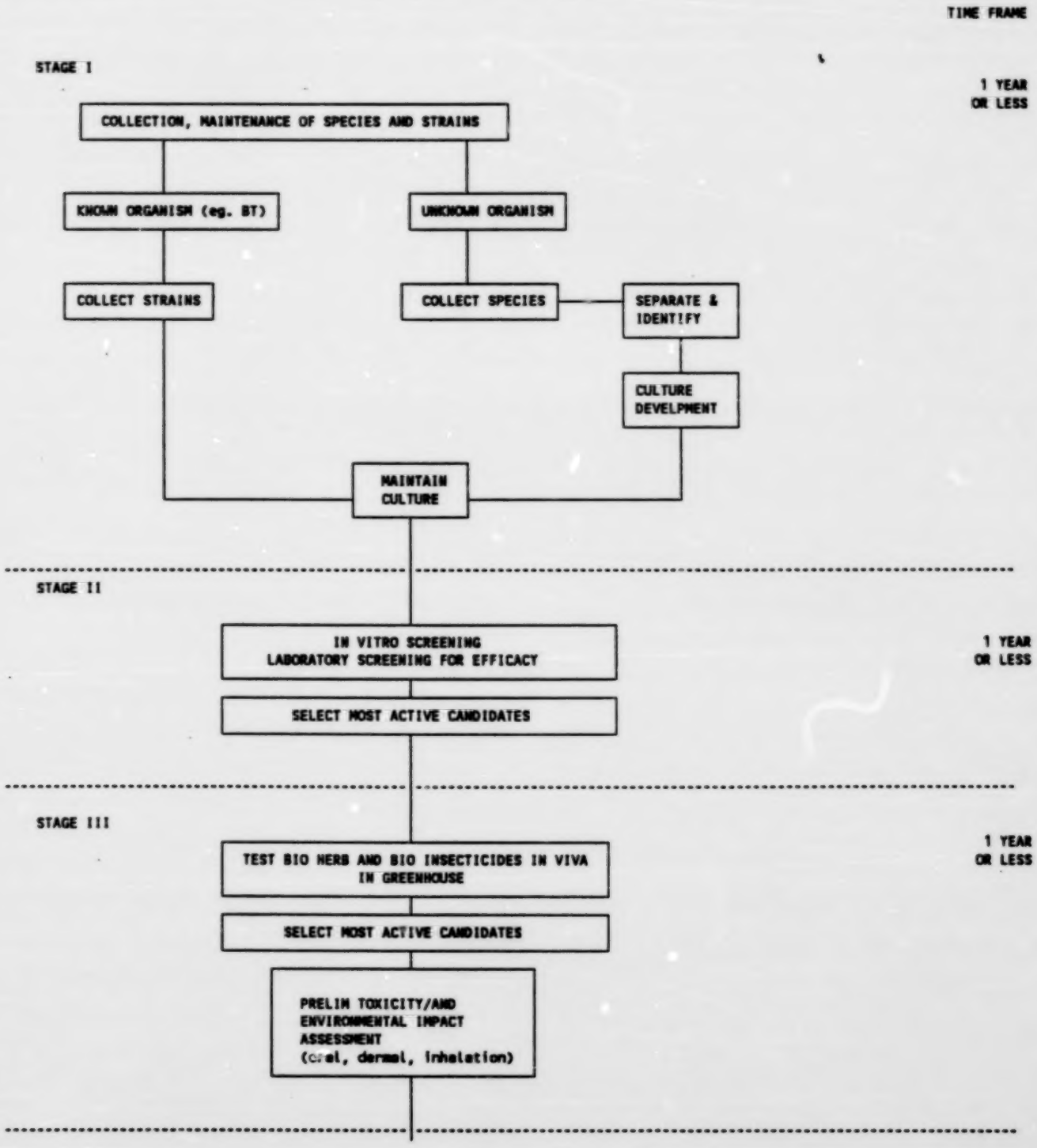


Figure 3 (Continued)

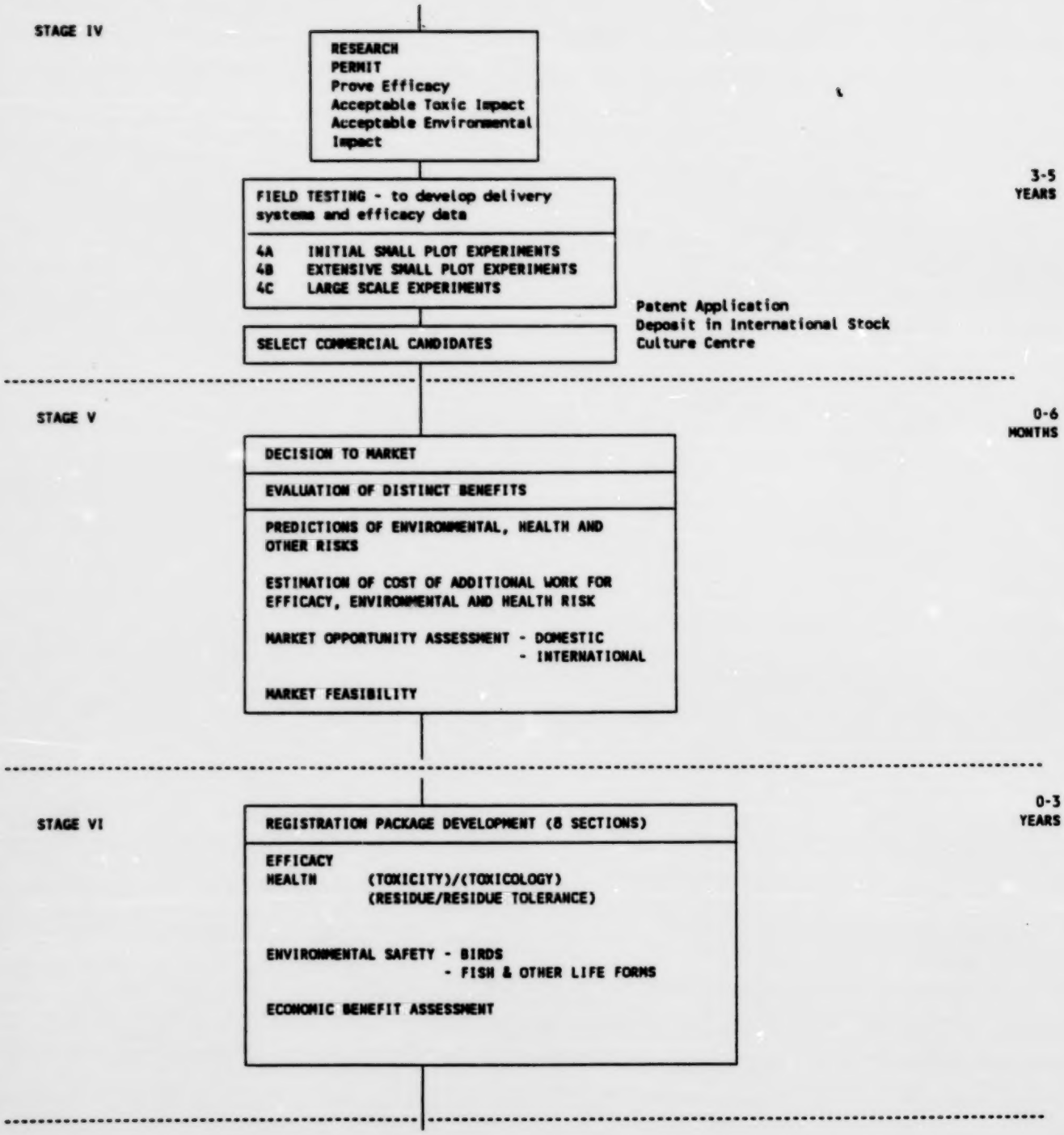
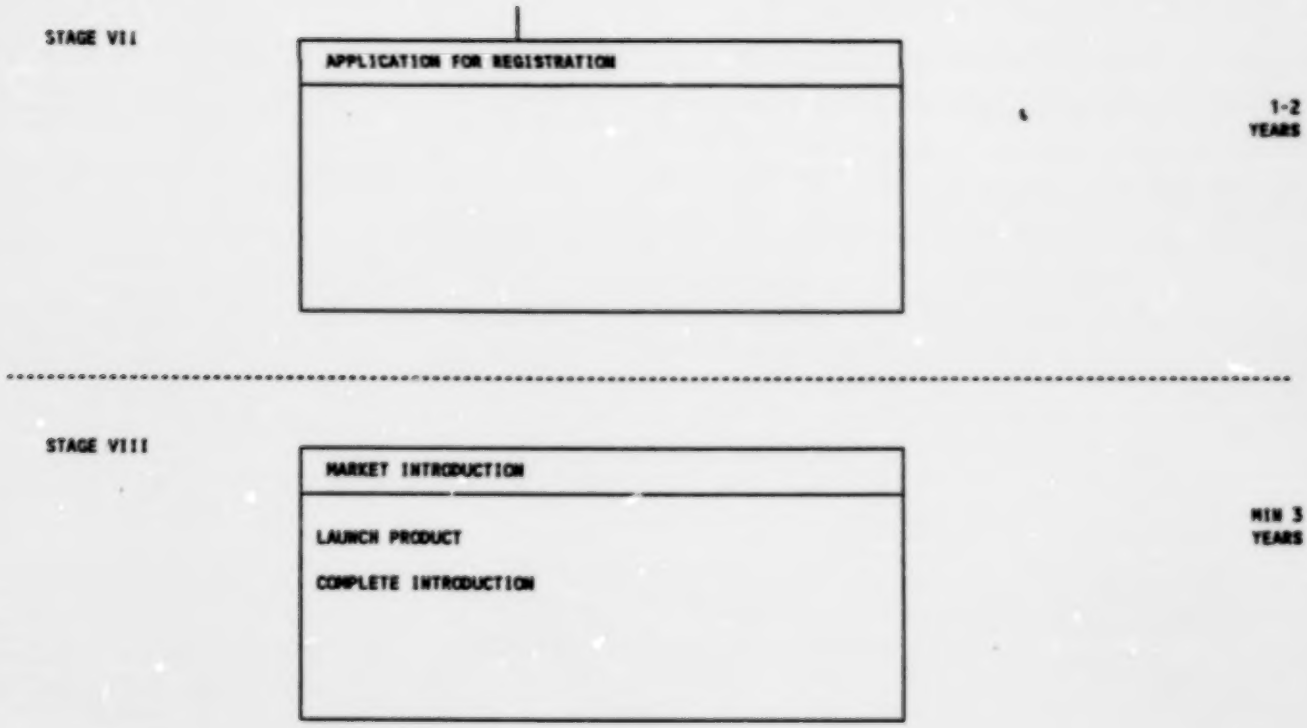


Figure 3 (Continued)



Stage 3 Greenhouse Screening

Selected species/strains that are candidates for control of plants or diseases are subjected to secondary screening in the greenhouse. The greenhouse should normally be "contained" to prevent accidental release of the organism into the environment. A further selection of candidate agents may take place at this stage. Preliminary evaluation of the selected candidate agents is conducted at this stage to indicate toxicity and environmental impact. This stage is similar to evaluation of chemical pesticides and can be completed in 1 year or less. Where the organism is of local origin, the greenhouse need not be contained.

Tests to evaluate the impact of the microbial control agent on non-target organisms are conducted at this stage. Preliminary evaluation of the safety of the organism to man should be conducted at this stage but in some cases this is deferred until after efficacy is established in the field.

Stage 4 Field Testing

Development of commercial recommendations for selected candidates is the objective of field testing. Several requirements must be met to achieve this:

1. Efficacy achieved in the laboratory and greenhouse must be confirmed in a field environment.
2. The necessary dose of the active ingredient to provide commercially acceptable control must be determined.
3. An effective and reliable delivery system must be developed.
4. The fate of the micro-organism must be determined.
5. The impact on non-target organisms must be determined.

A number of problems may be encountered at this stage. Scale-up of production to reach the levels required for field evaluation may result in a loss of potency or contamination of the culture. The micro-organism may not react in a field environment in the same way as it did in a contained environment. The delivery system for initial testing may prove to be unreliable. The fate of the micro-organism and its impact on non-target organisms may be environmentally unacceptable.

Before large scale field testing can commence in Canada, a research permit must be issued by Agriculture Canada. A pre-requisite of such a permit is the submission of scientific data on the following:

1. Proof that the agent shows promise of being efficacious.
2. Favourable preliminary toxicity data.
3. Favourable preliminary environmental data, including no significant activity against non-target organisms.

The permit process and requirements are still being evolved but are nearly in their final form.

Field testing will normally be conducted for several years even when no problems are encountered. For convenience testing may be sub-divided into three stages:

4A Initial small plot experiments. Research permit not required if testing confined to a research institute.
4B More extensive small plot experiments.
4C Larger scale experiments.

The regulatory requirements for the issue of research permits for trials not conducted at a research institute increase at each stage.

An absolute minimum of two years field testing is essential to ensure the product will perform reliably. Three years would be more normal for a product with no problems and five years would be common. Should problems be encountered, five years of field testing will be minimal.

Stage 5 Decision to Market

Irrespective of the organization that conducted the original research, at some stage the rights to market will be conferred on one or more companies. The identification of this

company depends on a number of factors. The various ways of selecting the company are listed below:

1. Company's own research will normally result in the same company having the marketing rights.

2. Company contracts research with a private, government or university research institution. In this case, the company will normally retain marketing rights.

3. If the original research was by a government or university research institution, that institution may enter into an agreement with a suitable company. Often an agreement which confers marketing rights will require the selected company to meet certain conditions such as funding continuing research at the institution, developing at its own expense the necessary safety and environmental data and seeking patent protection where appropriate.

The selected company should at Stage 5 decide whether or not it wishes to market the selected candidate control agent. It should base this decision on an evaluation of the following:

1. Is the candidate of use and does it offer sufficient advantage over other control measures to find acceptance in the market?

2. Is the preliminary evaluation of safety to health and to the environment positive and are any problems anticipated in these areas?

3. What will be the cost of developing additional data necessary to meet regulatory requirements and how long will this take?

4. What are the domestic and international market sizes and how much will it cost to develop them commercially once registration has been obtained?

Evaluation of these four factors will indicate the economic viability of the candidate. This process will normally take a few months to complete.

Stage 6 Development of Registration Data

Additional scientific investigations to produce final efficacy, health and environmental data should be commenced only when the company has decided to market the product. In some cases there may already be sufficient data to support registration. In other cases additional data may be required.

Stage 7 Obtain Registration under the PCP Act

The registration process for a new type of microbial control agent is a lengthy procedure. To minimize the period required to successfully conclude this stage it is important that the application be complete and correct in all details. Complete compliance with the research permit system will certainly aid in this process.

The time required to obtain registration will rarely be much less than one year even for an application that is complete in all respects and is fully accepted by the regulatory consultants involved. This stage is more likely to take up to two years for a new micro-organism and may require the development of additional data before it is granted.

Stage 8 Market Introduction

The market introduction process of a successful product will normally follow a set pattern. The first year will involve leading farmers willing to try a new product. This leads to more extensive use in the second year. It will normally be the third year before a new product can be confirmed as a success. In cases when there is an urgent need to control a major problem a successful product may achieve this position more quickly.

3.2 Cost and Time Requirements for Microbial Control Agents Development

The cost of developing microbial control agents for sale in Canada depends very much on the nature of the micro-organism and the time required to conduct the necessary scientific studies. An optimistic scenario for a micro-organism that performs in field tests in a manner similar to its performance in Stages 2 and 3, that is indigenous to the area in which

it will be used and that is not questioned by Health or Environmental officials would be about $1 million. The cost can be broken down as follows:

Data to Determine Efficacy

Stage 1	Collection
Stage 2	Laboratory screening
Stage 3	Greenhouse screening
Stage 4	Field trails
Stage 6	Final recommendations
	Total Efficacy $500,000

Data to Determine Safety to Human Health

Acute toxicity
Chronic toxicity
Total Health $250,000

Data to Determine Environmental Safety
Fate in the environment
Impact on non-target organisms
Total Environmental $250,000

Grand Total $1,000,000

These preliminary estimates of direct costs are considered minimal but require further investigation to confirm them. Potential products that face technical, health or environmental questions will cost more. These estimates do not include the costs of developing processes or formulations. Also, they do not include capital costs for laboratory, greenhouse, or plant construction or interest charged on costs incurred before trading commences.

The development period for microbial agents is quite unpredictable and depends on a number of factors:

1. Success in collecting active strains/species.
2. Whether the micro-organism is indigenous or exotic to the area in which it will be used.
3. Success in culturing the micro-organism.
4. Development of appropriate screening, greenhouse and field testing procedures.
5. Degree of risk to health and the environment.
6. Provision of complete and satisfactory data for research permits and registration.
7. Presence or absence of potency or contamination problems when production is scaled up.
8. Efficacy in the field compared to screening and greenhouse testing.
9. Development of an effective and reliable delivery system.
10. Development time for production process and formulations (see section 3.5).
11. Regulatory requirements for additional toxicity and environmental data.
12. Changes in research permit and registration procedures and requirements.
13. Processing of registration applications.

Table 1 shows a summary of the total time required to develop a microbial control agent and launch it on the market for two different scenarios. In both scenarios it is assumed that the micro-organism is indigenous to the area and that it presents no risk to health or the environment. In the most optimistic scenario an absolute minimum of four years is required from the time the project is initiated until the product is launched. Eight years is a more realistic development period, especially for a micro-organism for which there is no prior knowledge.

3.3 Stages in the Development of Naturally Occurring Microbial Inoculants

The development process for inoculants is similar to that for control agents but is usually less complex. This is largely because the purpose of inoculants is to enhance growth so they are perceived as being safer than control agents whose purpose is to control growth. These stages are identified below and summarized in Figure 4.

TABLE 1 ESTIMATED DEVELOPMENT PERIODS FOR AN INDIGENOUS MICROBIAL CONTROL AGENT

Stage	Activity	Most Optimistic Months	Cumulative Months	Realistic Months	Cumulative Months
1	Collection	2	2	14	14
2	Laboratory screening	2	4	14 + 2	16
3	Greenhouse tests	2	6	16 + 2	18
	Preliminary Toxicity and Environmental Data	3	9	3	21
4	Obtain Research Permit	3	12	3	24
	Field testing	18	30	30	54
5	Decision to market	0	30	6	60
6	Develop Registration Package	0	30	6	66
7	Registration	12	42	24	90
8	Planning product launch	6	48	6	96
	Launch product	6	54	6	102
	Complete product introduction	30	84	30	132

Stage 1 Collection and Maintenance of Species and Strains

This step is identical to that for microbial control agents. Prospective inoculants are first isolated, normally from the soil. They are then identified, purified and cultured.

Stage 2 Laboratory Screening

Each isolated species/strain may be screened in the laboratory to determine if it exhibits the desired activity.

Some organizations omit this stage and proceed directly to screening in a contained greenhouse. They use the laboratory only for special purposes such as studying specific enzymes that may be produced by some micro-organisms.

Stage 3 Greenhouse Screening

Isolated species/strains are evaluated in a contained greenhouse to determine if they enhance growth. Once the screening technique has been worked out, each assay will take about one month to complete. Numerous isolates can be tested in one period. The most active species/strains are selected for field testing.

Stage 4 Field Testing

Development of commercial recommendations for selected candidates is the objective of field testing. Several requirements must be met to achieve this:

1. Growth stimulating activity identified in the greenhouse must be confirmed in a field environment.
2. The necessary dose to provide commercially acceptable results must be determined.
3. An effective and reliable delivery system must be developed.
4. The fate of the micro-organism must be determined.

Some organizations test the selected micro-organisms to determine their acute toxicity before field testing begins but this is not a common practice.

Field tests will normally be conducted for three to five years before all requirements can be met. The most active isolate is selected during this process.

Stage 5 Decision to Market

The decision to market is based on an evaluation of the following:

1. Is the candidate of use and does it offer sufficient benefit to find acceptance in the market?
2. What will be the cost of developing any additional data to meet regulatory requirements and how long will this take?
3. What are the domestic and international market sizes and how much will it cost to develop them commercially once registration has been obtained?

This evaluation will indicate the economic viability of the candidate.

Stage 6 Collection of Additional Data for Registration Purposes

Stage 7 Obtain Registration Under the Fertilizer Act

Registration of a well known micro-organism such a Rhizobium is a fairly simple task. The more exotic and less well known micro-organisms will take much longer and may require the submission of data not normally required under the Fertilizer Act. This can include acute toxicity data and might in the future require chronic toxicity data, scientific proof of the mode of action and a thorough environmental package.

Stage 8 Market Introduction

The time required for establishing a successful microbial inoculant on the market is hard to predict since few have been introduced other than Rhizobium.

FIGURE 4 INOCULANTS - PATHWAYS OF DEVELOPMENT

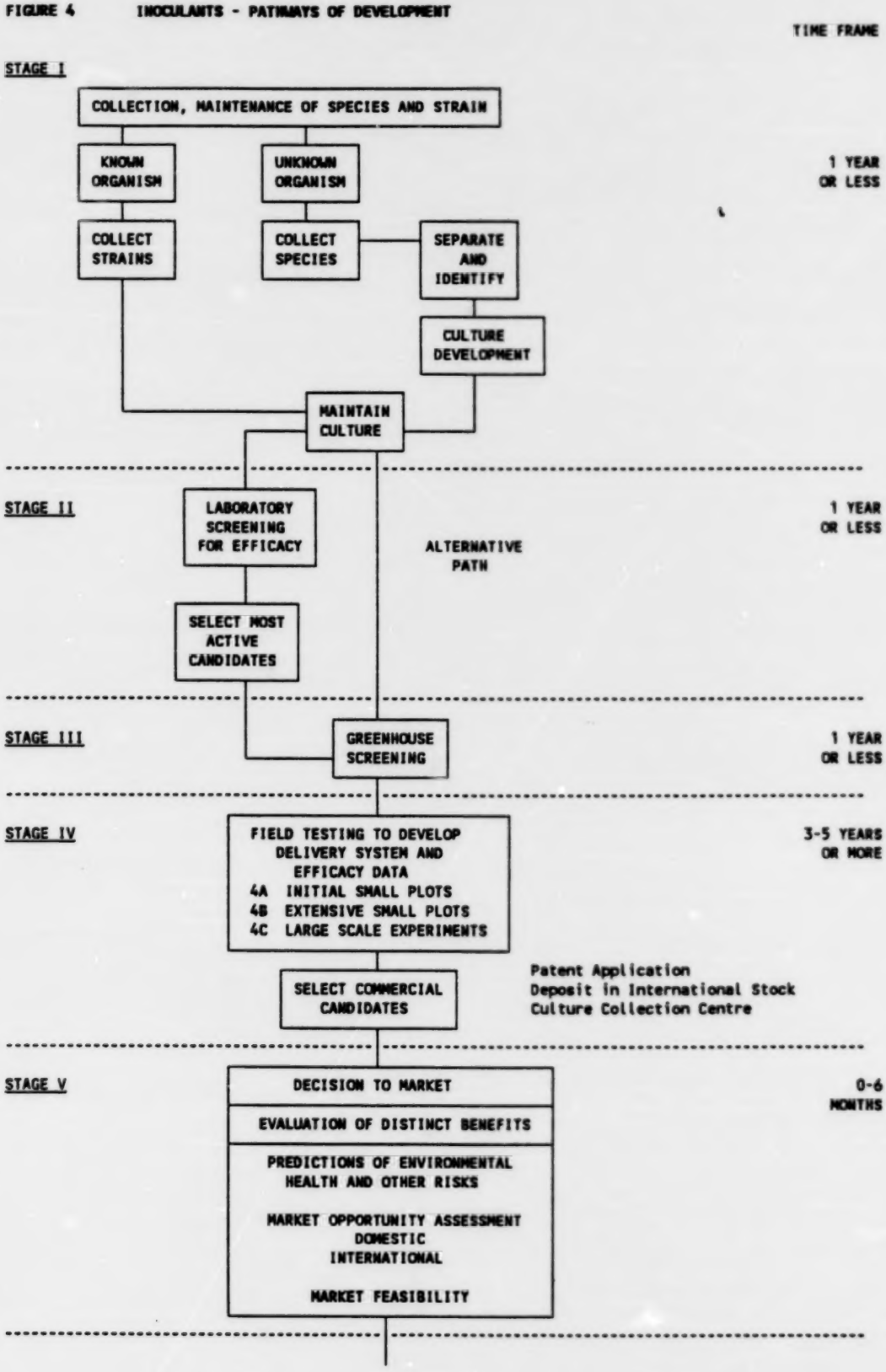
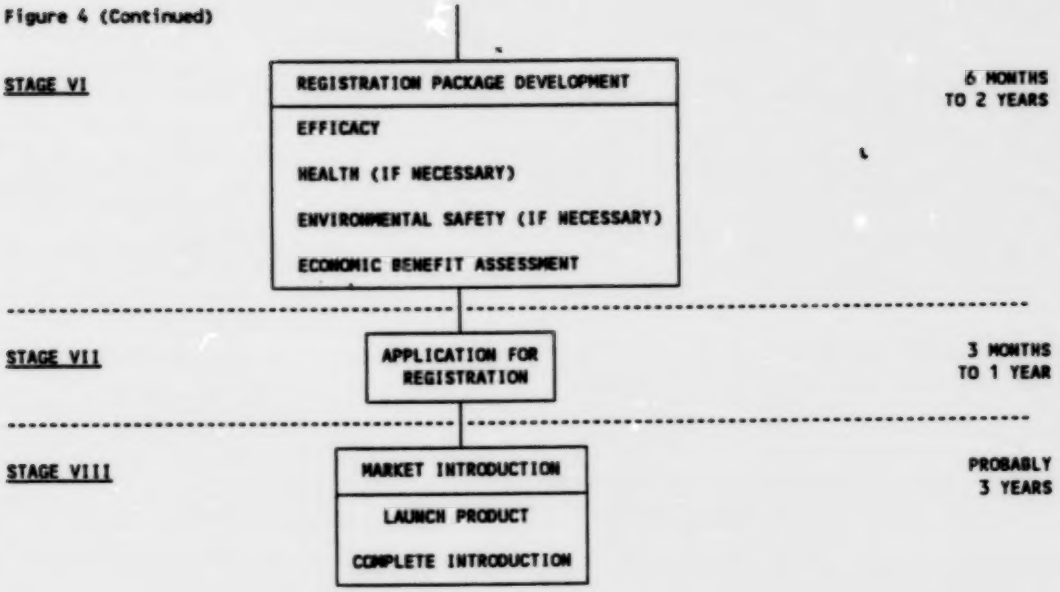


Figure 4 (Continued)



3.4 Cost and Time Requirements for Microbial Inoculant Development

The direct costs and time required to develop a microbial inoculant will depend very much on the nature of the micro-organism involved. Very little information is available on either of these factors but very preliminary estimates for costs of development are shown in Table 2 and for the time required for development in Table 3. In each table two scenarios are presented:

1. A well known micro-organism such as Rhizobium. Such a product can be developed in about two and a half (2 1/2) years at a cost of $200,000.

2. A micro-organism whose growth stimulating activity has been previously unknown. This type of product could well take 8 years to develop at a cost of $700,000.

3.5 Production Development for Microbial Control Agents and Inoculants

Most microbial control agents and inoculants are produced in an enclosed vessel called a bioreactor. The following requirements must be met:

1. A suitable growing medium must be developed for the specific organism.

2. Optimal environmental conditions for growth and multiplication of the organism must be determined. Examples of the factors that must be studied include temperature, oxygen levels and pH.

3. Methods for preventing contamination by other organisms must be developed.

4. For organisms that are applied live, methods must be developed for producing the organism in a suitable form for application in the field. This may mean that spore formation must be maximized.

5. The organism, toxin, or both must be separated from the growing medium.

TABLE 2 ESTIMATED COSTS FOR MICROBIAL INOCULANT DEVELOPMENT

STAGE	ACTIVITY	WELL KNOWN ORGANISM		PREVIOUSLY UNKNOWN ORGANISM	
		COST $000'S	CUMULATIVE COST $000'S	COST $000'S	CUMULATIVE COST $000'S
1-4	Complete testing	200	200	500	500
6	Acute toxicity data	0	200	100	600
	Environmental data	0	200	100	700
	TOTAL		200		700

TABLE 3 ESTIMATED DEVELOPMENT PERIODS FOR MICROBIAL INOCULANTS

STAGE	ACTIVITY	WELL KNOWN ORGANISM		PREVIOUSLY UNKNOWN ORGANISM	
		TIME REQUIRED MONTHS	CUMULATIVE TIME REQUIRED MONTHS	TIME REQUIRED MONTHS	CUMULATIVE TIME REQUIRED MONTHS
1	Collection	2	2	14	14
2	Laboratory screening	0	2	14+2	16
3	Greenhouse tests	2	4	16+2	18
4	Field testing	18	22	54	72
5	Decision to Market	0	22	6	78
6	Develop registration package	0	22	6	84
7	Registration	2	24	12	96
8	Planning product launch	6	30	6	102
	Launch product	6	36	6	108
	Complete product introduction	30	66	not known	not known

6. All of the above must be accomplished without a reduction in the potency of the control agent or inoculant.

Micorhizal fungi and viruses are not produced in this way. The former must be grown on living plants, while the latter are produced in live insects. In both cases, increased contamination risks are the rule.

3.6 Formulation Development for Microbial Control Agents and Inoculants

Micro-organisms can be classified in a number of different ways. Control agents of microbial origin can be grouped as follows:

1. Agents that utilize the ability of certain microbes to manufacture toxins. Many of the microbes themselves die during the production process and it is mainly the toxin that is applied to the crop. Bt is an example of this group.

2. Agents that contain live microbes but control the target by producing toxic components on the crop. Fungal and bacterial isolates that have been found to control grey mould on strawberries may be of this type.

3. Fungal, bacterial or Protozoan pathogens that infect targets which die from disease. Bio-Mal is an example of this type of agent.

Inoculants might be grouped as follows:

1. Inoculants that invade the crop roots. Rhizobium is in this category.
2. Inoculants that act on but not in the root.
3. Inoculants that act in the soil close to the roots, such as Penicillium bilaji.

Another way of classifying these micro-organisms is by the biological form in which they are applied. The following classes can be identified:

1. Toxins that act as control agents. The micro-organism does not have to be kept alive in the formulation. An example is Bt.

2. Micro-organisms that can be applied in the spore stage. An example is Bio-Mal.
3. Micro-organisms that do not form spores and must be kept alive in the formulation.

A third way of classifying these micro-organisms is by the part of the plant to be targeted.

1. Aerial part of plant. Micro-organism will normally be sprayed on. Examples are Bt and Bio-Mal.
2. Roots. Micro-organism may be broadcast but will often be applied with or on the seed.

An attempt to classify the type of formulation required for each application is shown in Table 4. Formulating products of microbial origin in which the micro-organism itself need not be alive is similar to formulating synthetic chemical products and does not require the development of special technology. Formulating microbial products in which the micro-organism is applied as a spore is also relatively easy. Such products must be in the wettable powder, dry seed dressing or granular form. Special measures will be necessary to prevent the spore from germinating before it is applied to the target.

The art of formulating microbial products in which the micro-organism is in the living form is in its infancy. Some may be able to survive in a peat medium but many cannot. This is an area that requires considerable research before solutions are found.

3.7 Stages in the Development of Production Methods and Formulations

The timing of production method and formulation development is a compromise between several factors, especially for control agents. These factors are:

1. The need to confirm that scaling up production from laboratory levels to commercial levels is not likely to result in a loss of potency. Normally this means that this work must be completed before or during stage 4.

2. The need to have usable formulations for use in stage 4.

TABLE 4 TYPES OF FORMULATION REQUIRED FOR MICROBIAL CONTROL AGENTS AND INOCULANTS

Target Area	Type of Application	Micro-organism Stage	Type of Formulation
Aerial part of plant	Spray	May be dead	Wettable powder solution Emulsifiable concentrate
		Spore	Wettable powder
		Free living	Probably liquid
Root	Seed treatment	May be dead	Liquid or dry seed dressing
		Spore	Probably dry seed dressing
		Free living	Probably liquid seed dressing or in peat
	Furrow treatment	May be dead	Liquid or granule
		Spore	Granule
		Free living	Probably liquid or in peat

3. The registration requirement that the actual active ingredient that will be produced for sale and the actual formulation to be sold must be evaluated in any required toxicity, residue, environmental and efficacy tests.

There are two alternative strategies that can be followed:

A. Rapid Stage Development

1. Develop preliminary production and formulation methods in Stage 3.

2. Conduct preliminary toxicity and environmental tests where required in Stage 3.

3. Use the same production method and formulation to complete the registration package in Stage 6.

4. Introduce the same product in Stage 7.

5. Improve production methods and formulation.

6. Complete a new registration package.

7. Introduce the new formulation as a product improvement.

B. Conservative Stage Development

1. Develop preliminary production and formulation methods in Stage 3.

2. Conduct preliminary toxicity and environmental tests where required in Stage 3.

3. Confirm field performance in Stage 4 and decision to market in Stage 5.

4. Improve production methods and formulation.

5. Use the improved active ingredient and formulation to re-confirm efficacy and complete the registration package in Stage 6.

6. Introduce the improved product in Stage 7.

Alternative A, Rapid Stage Development, offers prospects for earning revenue from which to finance production improvements. Alternative B, Conservative Stage Development, requires more pre-investment but will require less total investment in product development and should result in a better product for market introduction.

4.0 PERFORMANCE CHARACTERISTICS OF MICROBIAL CONTROL AGENTS

With the exception of Bt, there is little commercial scale information available on field performance of microbial control agents. However, there is considerable activity at the research level and twenty per cent of research permits issued by the Pesticide Directorate are for tests with this type of agent.

Microbial Control Agents must compete against synthetic chemical control agents if they are to be accepted in the market place. Attempts to project comparative performance between these two types of agent are outlined in Table 5 (Herbicides), Table 6 (Fungicides) and Table 7 (Insecticides).

From these tables, the following conclusions can be drawn:

1. Research on microbial herbicides should be directed toward specific weeds that are a major economic problem. The use of these herbicides should be considered in conjunction with the use of synthetic chemical herbicides or classical biological control systems.

2. Research on microbial fungicides has so far not been very successful. This is due to difficulties in duplicating laboratory results in the field. There is a clear case for more basic research to understand the reasons for this and provide solutions.

3. Microbial insecticides of the type which control the target with toxins or viruses appear to be the most likely area for success.

4. Development time will be lengthy and costly. This is partly due to the need to confirm the safety of the control agents to man and the environment. This means that it will be economically viable to research those items with large market potential only.

5. The many areas on which there is currently little information indicate a need for more basic research.

TABLE 5 PROJECTION OF COMPARISON BETWEEN MICROBIAL AND SYNTHETIC CONTROL AGENTS HERBICIDES

FACTOR	MICROBIAL CONTROL AGENTS	SYNTHETIC CONTROL AGENTS	REMARKS
Speed of control	Usually slow to very slow. (Speed of control may be affected by environmental factors at application time).	Usually quite rapid. In the case of pre-emergence treatment have almost a preventative action.	Microbial agents may be too slow to prevent yield supression.
Spectrum of control	Usually highly specific.	Usually control a range of broad-leaved or grass type weeds.	Microbial agents will often be limited to control of one species or possibly one genus.
Environmental impact	Due to their highly specfic action, not likely to impact other organisms besides the target weed.	Can have an impact on non-target organisms but usually this is mild.	Although microbials seem to be highly specific, regulators still require full assurance this is so.
Selectivity in weed populations	Highly selective. Probably will be used in conjuction with chemical agents.	Usually selective for some groups of weeds. This leads to the spread of other weeds and increasing use of herbicide mixtures.	Microbials appear to be most suited for use on specific weed problems.

Table 5 Continued

FACTOR	MICROBIAL CONTROL AGENTS	SYNTHETIC CONTROL AGENTS	REMARKS
Selectivity in crops	Expected to be highly selective in all crops not related to the target weed.	Never selective in all crops. May supress yields in some varieties of tolerant crops.	Microbials probably suited to highly specific problems.
Contamination	Not expected to contaminate ground or surface water.	Can contaminate ground and surface water. (Glyphosate is an exception)	Insufficient data on microbials to draw reliable conclusions.
Soil residues	Little evidence to date but no indications of problems.	Some synthetics can carry over in the soil from one season to the next and cause damage to succeeding crops.	Insufficient data on microbials to draw reliable conclusions.
Danger to surrounding area	Little evidence to date but no indication of problems.	Some can damage neighboring sensitive crops from spray drift.	Insufficient data on microbials to draw reliable conclusions.
Reliability	Performance related to environmental factors such as humidity. Several candidates which showed promise in the greenhouse did not perform well in the field.	Most are reliable when directions are followed.	Microbials appear to require more precise conditions, especially where speed of control is important.
Probability of Resistance	None demonstrated to date.	About 85 weed species have now developed resistance to herbicides.	There is potential for weeds to develop resistance to microbials.

TABLE 6 PROJECTION OF COMPARISON BETWEEN MICROBIAL AND SYNTHETIC AGENTS FUNGICIDES

FACTOR	MICROBIAL CONTROL AGENTS	SYNTHETIC CONTROL AGENTS	REMARKS
Field Performance	For the most part it has not been possible to duplicate control levels obtained in the lab in field experiments reliably.	Provide commercially acceptable control under most conditions when directions are followed.	The only microbial fungicide introduced in North America failed due to poor performance.
Spectrum of Control	Expected to be specific but not fully studied.	Contact action preventative products have a broad spectrum. Systemics tend to be quite specific.	Insufficient data on microbials to draw reliable conclusions.
Mode of Action	Not known but may be by production of endotoxins.	Well documented.	Considerable additional study required on microbials.
Health Hazards	Not expected to be a problem but this will ultimately depend on the nature of any endotoxins that are produced.	Some are suspected as being a health hazard.	Insufficient data on microbials to draw reliable conclusions.
Environmental Impact	Not expected to be a problem but this will ultimately depend on the nature of any endotoxins that are produced.	Appears to have a generally good record.	Insufficient data on microbials to draw reliable conclusions.
Possibility of Resistance	Not known. Will depend on mode of action.	In no case has disease developed resistance to contact preventative fungicides. Systemic fungicides are prone to this problem.	No information on microbials.
Speed of Action	Appears to be rapid.	Usually rapid.	Mode of action of microbials needs to be determined.

TABLE 7 PROJECTION OF COMPARISON BETWEEN MICROBIAL AND SYNTHETIC AGENTS INSECTICIDES

FACTOR	MICROBIAL CONTROL AGENTS	SYNTHETIC CONTROL AGENTS	REMARKS
Field Performance	Commercially available products are quite reliable but still suffer from contamination problems.	Proved as quite reliable but do not eliminate the problem.	Synthetic agents are often superior.
Spectrum of Control	So far limited to a single genus or insect family.	Variable. Depends on specific chemical but generally broader spectrum control than microbials.	Attempts are being made to broaden the control from Bt. And one such product is registered in the U.S.A. Synthetics can affect non-target desirable insect species thus inducing more economic problems.
Health Hazards	Have a reputation for safety.	May require careful handling to avoid exposure. Can result in unacceptable residues when used contrary to directions.	Insufficient data on microbials for reliable assessment. There is a perception that microbials are safer.
Environmental Impact	Bt appears safe. Little known about other agents.	Persistent synthetics have been shown to enter the food chain and disrupt it. Few problems encountered from short residual synthetics except in specific cases such as forest spraying.	Insufficient data on microbials for reliable assessment, except for Bt on forests which appears to be safe.
Probability of Resistance	Not known.	Insects and mites can develop resistance.	Insufficient data on microbials for reliable assessment.
Speed of Control	Usually slow to very slow.	Usually rapid.	Slow action may deter acceptance in intensive crop production.

6. There are a significant number of cases in which field performance has not matched laboratory performance. In many of these cases performance has proven to be unreliable. This indicates that there is a fairly high risk that commercially acceptable products cannot be developed until there is a better understanding of the interaction between organisms in the field and significant formulation improvements have been developed.

5.0 MARKET SIZE

5.1 Market Size for Control Agents

Some ideas of the potential markets for microbial control agents can be gained from an understanding of the current markets for synthetic chemical control agents. The following comments are based on confidential marketing data supplied by Ciba-Geigy Limited, Basle, Switzerland.

In spite of its large size, Canada is a relatively small consumer of chemical pesticides accounting for less than four percent of world consumption. Fungicide consumption is particularly low being less than one percent of world consumption. Insecticide consumption is also low at little more than one percent of world consumption. Only herbicides in Canada are of any relative significance and amount to more than six percent of world consumption of which about three quarters are used in the Prairie Provinces.

If we define a large market as one which exceeds C$250 million dollars in value at the manufacturers level a total of seventeen such markets exist in the world. Of these, seven are located in the Far East, four each in Western Europe and U.S.A. but only one each in Canada and the whole of South America. Thirteen of these major markets are identified in Table 8. The remaining markets are on crops not grown in Canada.

The intensity of farming operations is a major factor which influences pesticide use. The Far Eastern farmer must practice very intensively if the massive population in that area is to be fed. Farmers in Western Europe and U.S.A. also farm intensively, partly because they are encouraged to do so by farm subsidy programs. Compared to these zones only small areas in Canada are farmed intensively. These are located mainly in Eastern Canada. Prairie farming is more extensive than intensive due to the low rainfall in the area, but the trend in the Prairies is toward more intensive farming with higher fertilizer use, more sophisticated herbicide programs and production of higher value crops.

TABLE 8 MAJOR WORLD MARKETS FOR SYNTHETIC CONTROL AGENTS USED ON CROPS GROWN IN CANADA

Type of Control Agent	Crop	Canada	USA	South America	Western Europe	Far East
Herbicide	Corn		X			
Herbicide	Soyabean		X	X		
Herbicide	Small grain cereals	X			X	
Fungicide	Cereals				X	
Fungicide	Fruits, Nuts and Grapes				X	X
Fungicide	Vegetables					X
Insecticide	Corn		X			
Insecticide	Fruits, Nuts and Grapes				X	X
Insecticide	Vegetables					X
TOTAL		1	3	1	4	4

Herbicides used in small grain cereals is the one major market for chemical pesticides in Canada. Locally available estimates indicate that wild oat control accounts for the largest sector of this market. This exceeds $100 million annually. Wild millet (Setaria viridis) is also an important and growing sector.

Herbicides used in oil seed crops also form an important market. Although somewhat less than half the value of the small grain cereal herbicides it still ranks as the second largest market in Canada.

5.2 Market Size for Inoculants

The size of the present market in Canada has not been estimated at this stage but is believed to be small and almost entirely comprised of products for nitrogen fixing in leguminous crops. Use of such inoculants on soybeans and alfalfa for example is now a common practice. Use levels in soybeans in Ontario was estimated at two thirds of the planted acreage in Ontario[1]. Similar levels of inoculant use are expected in alfalfa seeding.

From a fertilizer replacement perspective the world consumption of fertilizer is shown in Table 9. The concentration of usage is in Eastern Europe and Russia, Western Europe, North America, China, the Far East and South America. Canada's fertilizer usage is between 1.5 and 1.7 percent of world totals for nitrogen, phosphate and potash. The value of this market is some $1.3 billion in total. There appears to be a significant potential market for products that improve phosphate utilization, germination, early growth and drought resistance.

[1]Deloitte & Touche Syndicated Crop Survey

TABLE 9 CONSUMPTION OF FERTILIZER PRODUCTS, 1987/88 BY REGION

Region	Proportion of Nitrogen	World Consumption Phosphate	Potash
		% Total Consumption	
North America	14.1	11.8	17.7
Western Europe	14.6	14.0	19.8
Latin America	1.1	7.8	8.6
Near East	5.3	4.4	0.5
Far East	3.9	11.2	7.5
Asia (Centrally Planned)	23.6	13.0	5.0
Eastern Europe & Russia	21.4	30.3	36.3
Other	9.6	7.5	4.6
TOTAL	100	100	100
TOTAL VOLUME (OOO metric tonnes)	76,040	36,948	27,539

Deloitte & Touche

IDENTIFICATION PRÉLIMINAIRE DE POSSIBILITÉS STRATÉGIQUES DE MISE AU POINT D'INOCULANTS ET DE PRODUITS DE LUTTE BIOLOGIQUE AU CANADA

SOMMAIRE

Deloitte & Touche a effectué une étude préliminaire en vue d'identifier des possibilités stratégiques au Canada dans le domaine des pesticides et inoculants microbiens. L'étude avait été commandée par Industrie, Sciences et Technologie Canada (ISTC).

Notre étude comprenait des interviews et des discussions avec un échantillon de personnes clés actives dans la recherche et la mise au point de produits microbiens et appartenant à des universités, à des organismes gouvernementaux et de réglementation et au milieu des affaires.

Nous avons consulté des études et articles scientifiques publiés, de l'information interne et des données industrielles, en vue de déterminer l'importance des problèmes posés par les ravageurs, les mauvaises herbes et les maladies, ainsi que les possibilités offertes par les inoculants.

Les conclusions de notre étude préliminaire sont les suivantes :

1. Les inoculants et agents microbiens naturels sont potentiellement des produits efficaces pour l'agriculture et la foresterie.

2. De nombreuses recherches actuellement en cours au Canada portent sur les inoculants et agents de contrôle microbiens, mais la plupart sont axées sur des solutions à des problèmes spécifiques et constituent par conséquent une réaction aux conditions présentes et non une initiative stratégique. Il existe quelques exceptions à cette situation, mais le niveau de succès est faible dans ces cas.

3. Au Canada, la recherche sur les inoculants est aussi considérablement développée et elle produit de bons résultats lorsque la mise au point des produits utilise des micro-organismes bien connus. Le niveau de réussite est beaucoup plus bas lorsque la mise au point des produits se fonde sur des concepts nouveaux.

4. Les conclusions 2 et 3 susmentionnées indiquent qu'il est nécessaire d'effectuer plus de recherches fondamentales pour mieux comprendre le mode d'action de nouveaux inoculants et agents de contrôle potentiels, leurs applications et leurs utilisations concrètes dans le secteur de l'agriculture.

5. Les personnes engagées dans la mise au point de produits microbiens ont tendance à sous-estimer le temps nécessaire pour atteindre l'étape de la commercialisation. On peut s'attendre à ce que les produits utilisant des souches améliorées d'organismes bien connus exigent une période de mise au point d'au moins trois ans, ou même de cinq ans, selon une estimation plus réaliste. Lorsque les produits se

fondent sur de nouveaux concepts, la période de mise au point est beaucoup plus longue. À mesure qu'on accumule des connaissances, ces périodes de mise au point peuvent être raccourcies, mais très peu seulement.

6. D'autre part, les coûts de la mise au point ont souvent été sous-estimés. Les coûts directs de la mise au point d'un nouvel agent de contrôle microbien efficace sont rarement inférieurs à 1 million de dollars et, pour un inoculant, ils s'élèvent à environ 700 000 dollars. Ces chiffres ne tiennent pas compte du coût de la mise au point d'un processus de production ou de formulations, ni des problèmes spéciaux qui pourraient se poser durant la mise au point du produit.

7. À cause de la nouveauté de cette science, il existe un risque élevé de se heurter à des problèmes considérables pendant la mise au point des produits. Mentionnons qu'une importante société, qui emploie des scientifiques exceptionnels, a dépensé 10,2 millions de dollars en huit ans et n'a pourtant pas encore lancé son premier produit.

8. Le processus de mise au point du produit doit inclure l'étude du micro-organisme choisi, en vue de garantir que la production et la commercialisation ne nuise pas à l'homme ni à l'environnement. Au Canada, le coût actuel de ces études est environ trois fois plus élevé qu'aux États-Unis.

9. Ces observations nous permettent de conclure que seules les principales possibilités visées sont probablement viables économiquement. Celles-ci sont les suivantes :

Herbicides	Insecticides	Fongicides	Inoculants
Avoine stérile	Tordeuse de bougeons de l'épinette	Tavelure des pommes	Fixation de l'azote
Vulpin	Insectes de sol	Brûlure tardive	Solubilisation du phosphate
Chiendent	Chrysomède des racines de maïs	Botrytis	Stimulants de de croissance
Mauvaises herbes vivaces nuisibles	Parasites de légumes	Maladies du sol	
Mauvaises herbes vivaces nuisibles dans les forêts			

10. Nous avons conclu que la mise au point de produits à base de micro-organismes naturels entraînera une expansion considérable des connaissances scientitifiques et que celles-ci serviront à mettre au point de produits à base de micro-organismes obtenus par les techniques du génie génétique. Finalement, ces micro-organismes remplaceront probablement les micro-organismes naturels, mais seulement après de nombreuses années.

11. Étant donné que la majeure partie de la recherche microbienne effectuée au Canada par les sociétés multinationales se limite à l'essai local de produits mis au point à l'étranger, il faudra examiner d'autres mécanismes de développement. On pourrait par exemple encourager les chercheurs scientifiques en leur accordant des subventions à la condition qu'ils acceptent des principes régissant l'exploitation des résultats positifs de leurs recherches.

12. Pour certaines personnes, le champ des possibilités stratégiques considérées peurra sembler limité; d'autres estimeront qu'il néglige beaucoup de problèmes et de possibilités. Pourtant, si l'on tient compte de la capacité du Canada de mettre en oeuvre efficacement une quelconque initiative stratégique, cette liste est encore beaucoup trop longue. Des progrès substantiels ne seront réalisables que dans quelques-uns de ces domaines, à cause de l'étendue des activités supplémentaires de recherche et de mise au point qu'il sera nécessaire d'effectuer et des ressources qu'exigera éventuellemet la commercialisation.

RECOMMANDATIONS

Dans le cadre de nos activités de recherche préliminaires, nous avons identifié une gamme de possibilités stratégiques dans le domaine des inoculants et des produits de lutte biologique. Cette identification se fonde sur des évaluations préliminaires de l'échelle de la possibilité, de la nature du problème et des pratiques actuelles de contrôle ou de traitement.

Les résultats de notre recherche nous encouragent fortement à recommander de déployer des efforts très concentrés sur un petit nombre de possibilités stratégiques (4 ou 5), c'est-à-dire sur la mise au point d'au moins un herbicide, un fongicide, un insecticide et un ou deux inoculants. Seul ce degré de concentration pourra générer le savoir-faire approfondi, le niveau d'effort, la reconnaissance et le potentiel de réussite dans des domaines importants. Nous estimons que cela s'impose, si l'on veut attirer l'attention et le soutien de sociétés multinationales et de sérieux investisseurs commerciaux canadiens. En outre, cela créera un meilleur environnement pour la mise au point directe et spontanée de solutions efficaces, en ce qui concerne les possibilités clés visées.

Par conséquent, il faudra choisir soigneusement le petit nombre de domaines à étudier. À cet égard, il importe que la nature et l'échelle des possibilités soient précisées et quantifiées en détail et que, du point de vue scientifique, les chances de réussite soient raisonnablement favorables. Nous estimons qu'il est essentiel de considérer toutes ces questions avant la désignation finale de toute possibilité stratégique.

Dans le cadre de nos activités de recherche préliminaires, nous avons aussi identifié des obstacles importants à la commercialisation efficace d'inoculants et de produits de lutte biologique, notamment :

- les délais, les coûts, l'incertitude et les risques associés à la mise au point des produits;
- la compréhension limitée des modes d'action des inoculants et des produits de lutte biologique;
- l'infrastructure et les ressources limitées, en ce qui concerne la commercialisation de tels produits au Canada et à l'étranger;
- les exigences relatives à la sécurité et à l'environnement, plus strictes qu'aux États-Unis;
- la forte préoccupation latente du public à l'égard de la sécurité humaine et environnementale, qui pourrait facilement et réalistement se porter sur cette activité à mesure que le public sera mieux informé sur les modes d'action et de contrôle;
- un certain manque de coordination entre les personnes engagées dans la recherche et dans le développement commercial.

Par conséquent, il importe d'étudier plus en détail la nature et l'échelle de ces problèmes et obstacles, si l'on veut élaborer des stratégies visant à les réduire ou à les éviter, pour être en mesure d'exploiter efficacement les possibilités stratégiques.

Néanmoins, on observe actuellement beaucoup d'enthousiasme et d'activité dans ce domaine. Pour promouvoir ce développement stratégique, il faudra continuer à fournir le soutien, le leadership, l'orientation et la coordination nécessaires.